How to Calculate the Embodied Carbon of a Concrete Mix - factsheet

A simplified calculation to understand potential carbon reductions in concrete mix when accurate data (EPD) is not available.

This fact sheet provides a simple way to calculate potential carbon reductions when an Environmental Product Declaration (EPD) is not available. It focuses on the 'cradle to gate' product stage carbon (A1-A3). Whenever possible, we encourage you to use data directly from the EPD for the concrete mix.

This fact sheet covers:

- An introduction and background to concrete embodied carbon
- A method for calculating product stage carbon (A1-A3), including the impact of cement, aggregate, water, supplementary cementitious materials and admixtures
- Carbon dataset for your calculations
- A worked example for reference.

Background

Concrete is the most widely used construction material in the world and is responsible for 6-10% of global carbon dioxide (CO_2) emissions. Portland cement is the primary ingredient in concrete and is responsible for most of concrete's carbon emissions. The proportion of ingredients in a concrete mixture can greatly influence its carbon impact.

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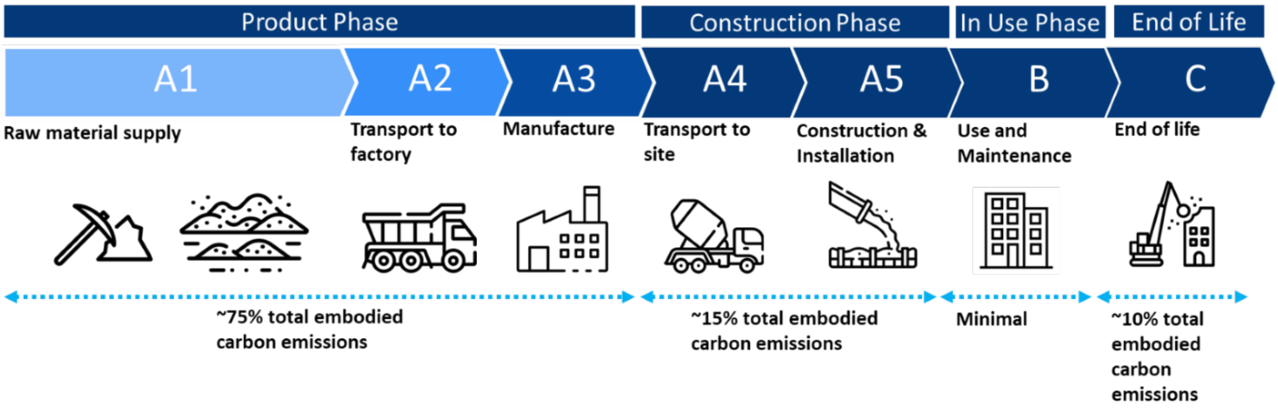

Figure 1. The approximate proportion of carbon associated with each of the life cycle stages. For further reference on the impact of each stage see the IStructE Short guides to carbon factors by Arup here.

The global warming potential (referred to in this document as 'carbon') for concrete can vary depending on raw material extraction, processing and manufacturing techniques, supplementary cementitious materials, admixtures, transportation mode and distance, concrete strength requirements and use of water. Additionally, the source of the data for the life cycle indicators (or carbon factors) will impact the overall carbon calculated for a concrete mix.

Methodology

Use the following approach to calculate the carbon impact of a concrete mix:

1. Identify the quantities of each ingredient in line with the concrete mix design
2. Select the suitable carbon intensity factor for each the constituent material from Table 1
3. To obtain the equivalent carbon impact of each ingredient, multiply the quantity of each constituent (e.g. cement) with the carbon factor for that constituent (in this example the cement carbon factor). This will give you the carbon impact of each constituent of the mix.
4. To obtain the carbon impact of the concrete mix, add the calculated carbon impact of each ingredient from Step 3.

$$\begin{matrix}\text{Carbon impact of} \\ \text{concrete mix} \\ (kgCO2e/m3)\end{matrix} = \sum \begin{matrix}\text{Quantity} \\ \text{of constituent} \\ (kg/m3)\end{matrix} \; x \; \begin{matrix}\text{Carbon emission} \\ \text{factor for constituent} \\ (kgCO2e/kg)\end{matrix}$$

5. You can calculate the carbon reduction between mixes by comparing them to a baseline concrete. The reduction is calculated as follows:

$$\begin{matrix}\text{Carbon} \\ \text{reduction (\%)}\end{matrix} = \left[1 - \left(\frac{\text{Carbon impact of reduced carbon mix}}{\text{Carbon impact of baseline mix}} \right) \right] x\ 100$$

A worked example is provided at the end of this factsheet in Table 2 and Table 3.

Carbon Dataset

If an EPD is available for the concrete mix, use this for the embodied carbon and carbon reduction. If an EPD is not available, you can calculate the embodied carbon of a concrete mix using greenhouse gas intensity factors (also known as carbon factors or life cycle indicators).

This factsheet uses the A1-A3 intensity factors sourced AusLCI (V1.42) Carbon Emissions Factors (Construction) (https://www.alcas.asn.au/auslci-emissions-factors) presented in Table 1. These factors are based on AusLCI and on a shadow database using Ecoinvent data, regionalised to Australia. There are various LCI databases globally and within Australia. To assess carbon reductions in your project, we recommend using Table 1. If a project wishes to use more current data, such as an EPD for cement, it can replace the value, as long as it is lower than the baseline in Table 1.

Table 1 Intensity factors (Life cycle stages A1-A3) taken from Infrastructure Sustainability Materials Calculator V2.0.13 (LCI 2021)

Name	LCI Source	Global Warming Potential (kg CO2e/tonne)
Alkali activator (Sodium silicate)	AusLCI Shadow database	1099.1
Cement	AusLCI	966.9
Coarse Aggregates (Gravel, crushed)	AusLCI Shadow database	10.5
Fine Aggregates (Sand)	AusLCI Shadow database	4.2
Fly ash	AusLCI	19.8
GGBF slag	AusLCI	192.2
Mains water	AusLCI Shadow database	0.4
Manufactured sand (Gravel, crushed)	AusLCI	10.5
Recycled Aggregates	AusLCI	5.1

Worked Example

This example shows the carbon assessment of a 40 MPa 'baseline' mix compared to a 40MPa mix with a 45% carbon reduction target. The 40 MPa mix is as an example to show the embodied carbon calculation. Note that the quantities used in this example are typical values for a 40 MPa mix and are not to be taken as a mix design. Note the above global warming potential factors have been provided as per kg, rather than tonne. This is to allow calculations of 1m^3 of concrete.

Table 2 Example of embodied carbon of a baseline 40 MPa concrete mix

Mix Constituents		Quantity (kg/m^3)	Global Warming Potential Factor (kg CO_2e/kg)	Total Global Warming Potential (kg CO_2e/m^3)
Cement	OP Cement	400	0.97	386.76
Supplementary Cementitious Materials	Fly ash	-	0.02	-
	Ground Granulated Blast Furnace Slag (GGBFS)	-	0.19	-
Coarse Aggregates	Coarse aggregate	1050	0.011	11.01
	Recycled concrete aggregate (RCA)	-	0.0051	-
Fine Aggregate	Fine aggregate	770	0.0042	3.23
	Manufactured sand	-	0.011	-
Admixtures	Superplasticiser[1]	2.15	2.2	4.73
Water	Mains Water	180	0.0004	0.08
			Carbon impact of baseline mix (kgCO2e/m^3)	**405.81**

[11] The carbon impact of superplasticiser admixtures is not included within the AusLCI database. Therefore, based on a review of the academic papers and available EPDs, a value of 2,200kgCO2e/kg has been used (*M.A. DeRousseau, J.H. Arehart, J.R. Kasprzyk, W.V. Srubar, Statistical variation in the embodied carbon of concrete mixtures, Journal of Cleaner Production, 2020*). This factor can be substituted with information available from manufacturers when more accurate information is available. Suppliers should provide information to justify the selected carbon intensity factors for admixtures to support the carbon reduction assessment.

Table 3 Example of embodied carbon of a 40 MPa concrete mix with a 45% emission reduction target compared to the baseline.

Mix Constituents		Quantity (kg/m^3)	Global Warming Potential Factor ($kg\ CO_2e/kg$)	Total Global Warming Potential ($kg\ CO_2e/m^3$)
Cement	OP Cement	160	0.97	154.70
Supplementary Cementitious Materials	Fly ash	-	0.02	-
	Ground Granulated Blast Furnace Slag (GGBFS)	240	0.19	46.13
Coarse Aggregates	Coarse aggregate	1050	0.011	11.01
	Recycled concrete aggregate (RCA)	-	0.0051	-
Fine Aggregate	Fine aggregate	770	0.0042	3.23
	Manufactured sand	-	0.011	-
Admixtures	Superplasticiser	2.15	2.2	4.73
Water	Mains Water	180	0.0004	0.08
			Carbon impact of baseline mix ($kgCO2e/m^3$)	**219.89**
			Carbon reduction compared to baseline concrete	**46%**

A template has been provided below for reference.

Table 4 Template for Mix Design Details and equivalent embodied carbon emission

Mix Constituents		Quantity (kg/m^3)	Global Warming Potential Factor	Total Global Warming Potential
			(kg CO_2e/kg)	(kg CO_2e/m^3)
Cement	OP Cement		0.97	
Supplementary Cementitious Materials	Fly ash		0.02	
	Ground Granulated Blast Furnace Slag (GGBFS)		0.19	
Coarse Aggregates	Coarse aggregate		0.011	
	Recycled concrete aggregate (RCA)		0.0051	
Fine Aggregate	Fine aggregate		0.0042	
	Manufactured sand		0.011	
Admixtures	Superplasticiser		2.2 [2]	
Water	Mains Water		0.0004	
	Recycled/ reused water		0.0000	
Total mix embodied carbon (kgCO2e/m^3)				

[2] Consult manufacturer for factors or use Table 1 for factor from literature.